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ABSTRACT

Eye movements of 32 newspaper readers (ranging in age from 22 to 50 years) were measured as they viewed four pages of varying use of color and black-and-white photographs. The eye-fixation data recorded by a computerized apparatus showed precisely where subjects looked, in what order they processed information on the page, and how long and how many times they directed attention to photographs. Results indicated that color affects how readers look at a page and, if used in certain ways, can influence the scan path order. Results also indicated no significant differences in the number of fixations and the average length of total fixation on color versus black-and-white photographs. In addition, subjects completed recall and recognition tests about the photographs they saw. Results indicated no significant differences between the number of color photographs and black-and-white photographs that were recalled. However, the use of color significantly impacted recognition of the photographs. (Four tables and one figure of data are included. Contains 14 references.) (RS)

EYE-MOVEMENT IN NEWSPAPERS

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EYE-MOVEMENT IN NEWSPAPERS

Eye movements of newspaper readers were measured as they viewed four pages varying the use of color and black-and-white photographs. The data showed that color photographs can affect how readers look at a newspaper page and if used in certain ways can influence how the page is scanned. The fixation data also showed there were no significant differences in the number of fixations and the average length of total fixation on color versus black-and-white photographs.

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Eye movements of newspaper readers were measured as they viewed four pages varying the use of color and black-and-white photographs. The eye-fixation data recorded by a computerized apparatus showed precisely where subjects looked, in what order they processed information on the page, and how long and how many times they directed attention to photographs. This methodology was selected for this study based on earlier research indicating that fixation is an accurate way to measure the visual perception that occurs as people look at photographs.

Results showed that color affects how readers look at a page and if used in certain ways can influence the scan path order. When a black-and-white photographs is on the top of the page and a color photograph is on the bottom, readers fixate on the bottom photograph significantly earlier than when both photographs are color, both are black and white, or if the top photograph is color and the bottom photograph is black and white. Results also showed that there were no significant differences in the number of fixations and the average length of total fixation on color versus black-and-white photographs.

In addition, subjects completed recall and recognition tests about the photographs they saw. There were no significant differences between the number of color photographs and black-and-white photographs that were recalled. However, the use of color significantly impacted recognition of the photographs.

EYE-MOVEMENT IN NEWSPAPERS: A COMPARISON OF THE NUMBER OF FIXATIONS, FIXATION DURATION AND SCAN PATH DATA ON PAGES WITH COLOR AND BLACK-AND-WHITE PHOTOGRAPHS

When people read the newspaper their eyes move continually -- from two to five times every second -- as they scan and inspect the content of the pages. This movement of the eyes, which largely goes unnoticed by the reader, is necessary for a physiological reason. Detailed visual information, such as that contained in the stories and photographs of a newspaper, can only be obtained through the fovea, the small central area of the retina that has the highest concentration of photoreceptors (Noton & Stark, 1971). Eye movements (combined with head and body movements) are necessary to direct the fovea toward points of interest on the newspaper page.

During normal viewing of a stationary object such as a newspaper page, the eyes alternate between fixations, when they are aimed at a fixed point, and rapid movements called saccades. A fixation lasts between 200 and 500 milliseconds and 1 to 5 degrees of the visual angle of view is processed (Yarbus, 1967). It shows where attention is being directed at a particular point in time (Buswell, 1935).

Fixations are separated by rapid, jerky movements, or saccades, during which the eyes' focus changes to a new section of the newspaper page. Saccades are exceedingly quick and occupy only about 10% of the total time spent scanning information. Saccades rarely move the eye more than 15 degrees of visual angle (Yarbus, 1967).

As mentioned above, during a fixation the fovea is directed to only part of the newspaper page and as such, only part of the information that is available is selected at any time for intensive processing. Levy-Schoen (1983) points out that this may have the functional value of protecting the central processors in the brain from overload. At the next instant, a new part of the available information can be selected for further intake and processing. She says:

> The way the visual system plays this role of a selective and active interface between the individual and his environment is very impressive. For the experimental psychologist, this natural device is also remarkable. Since oculomotor activity is an overt behavior that is accessible to recording and measurement, it opens a door to the scientist interested in the organization of perceptual and cognitive processing. To the extent that eye movements are reliable correlates of the sequential centering of attention, we can analyze them in order to understand how thinking goes on. (p. 66)

Thus, how the eye moves across a newspaper page -- the path it follows and the places it stops -- can provide valuable insight into how readers perceive the information presented on the page. Eye-tracking data can show what a person is looking at, how long something is fixated on, and in what order items on the page are scanned.

This study seeks to determine how the use of color photographs affects the way readers look at a newspaper page and subsequently how their use affects recall and recognition. Although extensive research has been conducted on eye movement and on color, only a few studies have been conducted that apply eye-movement research and color research to newspapers. Thus, the fact remains that little is known about the use of color photographs in this traditionally black-and-white medium.

Yet, newspapers everywhere are using more color today. In a 1988 survey of members of the American Society of Newspaper Editors (Editor & Publisher, Sept. 1988), 63% said they are using more color on a daily basis than a year ago and 84% said that within the next 5 years they will be using even more. Finally, 89% said that by the year 2000, color will be even more important for newspapers of all sizes.

At face value, the use of color seems to be a good thing. Color seems to attract readers to stories. Color makes a newspaper feel more contemporary. It probably attracts younger readers who traditionally are not dependent upon the newspaper for information.

However, even after 25 years, much of color use in newspapers is uninformed. It lacks a sense of purpose; it is not used journalistically, and it is usually not even used functionally. Color often seems an "aimless vagrant on the page," utilized not as a communication and design tool, but as something added simply because it is available (Garcia & Stark, 1991). The push for color in newspapers, spurred on by technological advancements that allow it to be printed in less time and for fewer dollars, seems to outweigh other more compelling reasons to use it. If newspaper pages are going to be painted with color, answers must be found about how to use color most effectively to communicate messages, as opposed to just presenting a pretty package.

Method

For this study, eye-movement data were gathered to determine precisely where subjects looked, in what order they processed information on the page, and how long and how many times they fixated on photographs. In all, three different kinds of eye-movement data were gathered: (1) fixation order (scan path), (2) fixation frequency, and (3) fixation duration. These fixation measures are important to the study of newspaper design because they provide a way to record and quantify what is happening as a reader looks at the page.

Four newspaper pages were designed for the eye-movement test -- a front page, a sports page, a business page and a features page. Then four versions of each page were produced by varying the use of color or black-and-white photography on the two photographs that appeared on each page. Specifically, one version had two color photographs, another had two black-and-white photographs and the other two versions had one color photograph and one black-and-white photograph appearing in different positions.

Thirty-two subjects, ranging in age from 22 to 50, were divided into four groups of eight subjects each. Each subject in each group saw four different newspaper pages for 10 seconds.

Each page had a different combination of color and black-and-white photographs. Therefore, subjects in each group viewed the same four pages, but viewed different versions of these four pages depending upon which group they were in. This methodology allowed for the use of a Latin-square design which maximized the data obtained from each subject. Each subject also completed recall and recognition tests about the photographs they were exposed to.

Eye-movement data were analyzed using multiple analysis of variance (MANOVA), the least-significant difference procedure and *t* tests. Recall and recognition data were analyzed with *t* tests.

Dependent variables analyzed by the MANOVA procedure for each subject included the total number of fixations on the top photograph, the total number of fixations on the bottom photograph, the total duration of fixation time on the top photograph, the total duration of fixation time on the bottom photograph, the order of occurrence of the first fixation on the top photograph (scan path data for the top photograph) and the order of occurrence of the first fixation on the bottom photograph (scan path data for the bottom photograph).

The three factors that constituted the Latin-square factorial design included the experimental group (1 through 4), page (front, sports, business and feature) and treatment -- top photograph color/bottom photograph color (CT/CB), top photograph black and white/bottom photograph black and white (BT/BB), top photograph black and white/bottom photograph color (BT/CB), and top photograph color/bottom photograph black and white (CT/BB) (see Figure 1).

	CT/CB	BT/BB	BT/CB	CT/BB
Front page	Group 1	Group 2	Group 3	Group 4
Sports	Group 2	Group 1	Group 4	Group 3
Business	Group 3	Group 4	Group 1	Group 2
Features	Group 4	Group 3	Group 2	Group 1

Figure 1. The Latin-square design.

Results

The mean scores for the three dependent variables used in the Latin-square design are shown below in Tables 1, 2 and 3.

Table 1

Average Number of Fixations on the Top Photograph and the Bottom Photograph

	CT/CB	BT/BB	BT/CB	CT/BB
Front page	6.00/2.63 Group 1	2.00/1.00 Group 2	2.00/2.50 Group 3	2.75/2.38 Group 4
Sports	3.00/1.88 Group 2	3.88/1.88 Group 1	5.00/2.00 Group 4	2.88/1.63 Group 3
Business	2.50/1.88 Group 3	3.00/2.25 Group 4	4.43/1.57 Group 1	2.00/1.63 Group 2
Features	2.00/2.14 Group 4	2.43/1.14 Group 3	2.00/1.75 Group 2	7.14/1.86 Group 1
Average	3.42/2.13	2.84/1.58	3.32/1.97	3.58/1.87

Table 2

Total Duration of Fixation on the Top Photograph and the Bottom Photograph

	CT/CB	BT/BB	BT/CB	CT/BB
Front page	1.70/0.70 Group 1	0.47/0.26 Group 2	0.46/0.57 Group 3	0.86/0.53 Group 4
Sports	0.71/0.41 Group 2	1.06/0.44 Group 1	1.34/0.57 Group 4	0.73/0.34 Group 3
Business	0.64/0.44 Group 3	0.76/0.64 Group 4	1.08/0.44 Group 1	0.41/0.46 Group 2
Features	0.45/0.56 Group 4	0.61/0.34 Group 3	0.43/0.52 Group 2	1.48/0.72 Group 1
Average	0.89/0.53	0.73/0.42	0.82/0.53	0.87/0.51

Table 3

Mean Order of Occurrence of First Fixations on the Top Photographs and the Bottom Photographs

	CT/CB	BT/BB	BT/CB	CT/BB
Front page	10.13/21.86 Group 1	14.75/35.50 Group 2	26.13/26.50 Group 3	17.87/30.00 Group 4
Sports	8.88/28.75 Group 2	7.00/24.63 Group 1	13.25/22.75 Group 4	10.62/30.75 Group 3
Business	18.38/24.00 Group 3	12.50/27.63 Group 4	11.71/17.00 Group 1	16.88/29.00 Group 2
Features	13.57/22.57 Group 4	19.14/28.57 Group 3	15.00/23.38 Group 2	5.43/30.43 Group 1
Average	12.71/24.35	13.16/29.10	16.67/22.58	12.94/30.05

The MANOVA procedure yielded a significant *F* value on the factor of treatment for the order of the first occurrence on the bottom photograph (scan path data). Significant *F* values were also found on the factor of group for the number of fixations on the top photograph and for the total fixation duration on the top photograph (see Table 4). These significant *F* values only show that the population means are probably not equal. They do not tell which treatments and groups have significantly different means.

Table 4

Summary of MANOVA *F* Tests and Significance Levels for All Factors and Variables

	Group	Treatment	Page
Number of Fixations on Top Photograph	$F = 7.93$ $p < .01$*	$F = 0.51$ $p = .68$	$F = 0.35$ $p = .79$
Number of Fixations on Bottom Photograph	$F = 0.56$ $p = .65$	$F = 0.41$ $p = .74$	$F = 0.21$ $p = .89$
Total Duration of Fixation on Top Photograph	$F = 7.45$ $p < .01$*	$F = 0.37$ $p = .77$	$F = 0.48$ $p = .70$
Total Duration of Fixation on Bottom Photograph	$F = 0.72$ $p = .54$	$F = 0.23$ $p = .88$	$F = 0.15$ $p = .93$
Scan Path Data for Top Photograph	$F = 2.40$ $p = .07$	$F = 0.50$ $p = .68$	$F = 1.44$ $p = .23$
Scan Path Data for Bottom Photograph	$F = 1.32$ $p = .27$	$F = 2.89$ $p = .04$*	$F = 0.61$ $p = .61$

*Significant *F* values

The significant main effect of the scan path data for the bottom photograph according to treatment, $F(3,120) = 2.89$, $p<.05$, indicates that some of the total variation in the order of occurrence of the first fixation on the bottom photograph is due to differences among the four treatment groups.

A one-way analysis of variance using the least-significant difference range test was carried out to produce multiple comparisons among the four treatments and determine which treatments were different from each other. The LSD procedure showed that Treatment 3 -- a black-and-white photograph on the top of the page with a color photograph on the bottom of the page (BT/CB) -- was significantly different from Treatment 2 (BT/BB) and Treatment 4 (CT/BB) on the mean order of occurrence of the first fixation on the bottom photograph.

All of the means for the order of occurrence of the first fixation on the bottom photographs for the four treatment groups are listed in Table 3. The means for the order of the first fixation on the top photographs for the four treatment groups are also listed in Table 3.

To determine more specifically the nature of the differences in when the top and bottom photographs are scanned, t tests were used to compare the means of the order of occurrence of the first fixations on the top photographs to those on the bottom photographs for the four treatment groups. It should be noted that for this comparison, mean scores could be computed only when subjects fixated on both photographs on each page. If a subject fixated on only one photograph, the scan path data were considered incomplete and therefore not usable in this comparison of the overall scan path data.

Taking this restriction into account, in the CT/CB treatment the average first fixation on the top photograph occurred at the 6.44 position, while the average first fixation on the bottom photograph occurred at the 21.11 position, a difference of 14.67 fixations. In the BT/BB treatment, the average first fixation on the top photograph was at the 5.73 position of occurrence, while the average first fixation on the bottom photograph occurred at the 21.80 position, a difference of 16.07 fixations. In the BT/CB treatment, the average first fixation on the top photograph was 8.71, whereas the average first fixation on the bottom photograph was 15.41, a difference of only 6.71 fixations. Finally, in the CT/BB treatment, the average first fixation on the top photograph was 4.93, while the average first fixation on the bottom photograph was 24.71, a difference of 19.79 fixations.

Therefore, the first fixation on the bottom photograph in the BT/CB condition occurred relatively early in the overall scan path, whereas the first fixation on the bottom photograph in the BT/BB, CT/BB and CT/CB treatments occurred relatively late in the overall scan path, in comparison.

The results of the $\underline{t}$ tests for paired samples for the four treatment groups show significant differences between the order of the occurrence of the first fixation on the top photograph and the order of the occurrence of the first fixation on the bottom photograph in the CT/CB, BT/BB and CT/BB treatments, but not in the BT/CB treatment.

In a more generalized comparison, the difference between the occurrence of the average first fixation on the bottom photograph when it is in color or when it is in black and white became strikingly apparent. The mean occurrence of the first fixation on the bottom photograph when it is in color was 17.65, whereas the mean occurrence of the first fixation on the bottom photograph when it is black and white was 23.30, a difference of 5.65 fixations. The difference is significant $\underline{t}(22) = -2.54$, $\underline{p}<.05$.

In contrast to the scan path data for photographs on the bottom of the newspaper page, there was no statistically significant difference between the means of the occurrence of the first fixation on the top photograph when it is in color and the top photograph when it is in black and white. The mean of the first fixation for the color photograph was 8.52, whereas the mean of the first fixation for the black-and-white photograph was just slightly smaller, 8.46. The difference is not statistically significant, $\underline{t}(26) = .03$, $\underline{p}>.05$.

A $\underline{t}$ test was also used to compare the scan path data for the top photograph with the scan path data for the bottom photograph, regardless of whether the photographs appeared in color or black and white. The importance that position plays in determining when a photograph is fixated on during the overall scan path became apparent by the statistically significant difference in the averages of the first fixations to the two areas of the page. The average order of occurrence of the first fixation on the top photograph was 7.84, while the average order of occurrence of the first fixation on the bottom photograph was 22.04, $t(28) - -7.84$, $p<.001$.

The MANOVA procedure indicated there were no significant differences among the four pages for any of the variables. In other words, any variance of the dependent variables for the factor of page, was random.

However, the MANOVA procedure revealed a significant F value for the effect of group on the number of fixations on the top photograph and the total fixation duration on the top photograph. The least-significant differences procedure was used to pinpoint which groups were significantly different from the others. The total variation in the data for both the number of fixations on the top photograph and the total fixation duration on the top photograph was attributed to the difference in Group 1 from the other three groups. The data do not indicate why Group 1 might be different from groups 2, 3, and 4, but only that the difference exists.

The MANOVA tests for main effects did not reveal any significant differences regarding the number of fixations on color photographs and black-and-white photographs. Subjects fixated an average of 3.50 times on the top photograph when it was in color, compared to 3.08 times when it was in black and white. In addition, subjects fixated an average of 2.05 times on the bottom photograph when it was in color, compared to 1.73

times when it was in black and white.

In a more generalized comparison, the average number of times color photographs were fixated on was 2.78 times, compared to 2.40 times for black-and-white photographs. As revealed by the MANOVA test, none of these differences was statistically significant.

Although there may not have been any statistically significant differences between the total number of fixations on color and black-and-white photographs, there was a statistically significant difference when only the position of the photograph was taken into account. The average number of fixations on the top photograph, regardless of whether it was color or black and white, was 3.30 fixations, compared to an average 1.89 fixations on the bottom photograph. Thus, between the top and bottom positions, there was a difference of 1.41 fixations $t(123) = 4.81$, $p<.05$.

As with the total number of fixations on photographs, the MANOVA tests for main effects did not reveal any significant differences regarding the average fixation duration on color photographs and black-and-white photographs. Specifically, the average fixation duration on the top photograph when it was in color was 0.89 seconds, compared to 0.77 for black and white. For photographs on the bottom of the page, the average duration of fixation was 0.53 seconds total when the photograph was in color, compared to 0.47 seconds for black and white. In general then, subjects spent slightly more time fixating on color photographs than black-and-white photographs overall. The averages show they fixated for 0.72 seconds on color photographs, compared to 0.62 seconds on black-and-white photographs. The MANOVA tests showed that none of these differences was statistically significant.

However, the difference between the length of time subjects spent fixating on the top photographs and the bottom photographs, regardless of whether they were in color or black and white, was statistically significant. The top photograph was fixated for 0.83 seconds, compared to the bottom photograph which was fixated for 0.50 seconds. Therefore, the top photograph was fixated on for 0.33 seconds more, $t(123) = 4.17$, $p<.05$.

In addition to the eye-movement information, recall and recognition data were collected to determine whether color facilitated the recall and recognition of photographs. When subjects were asked to lists all of the photographs they could recall after the 10-second exposures to each of the four pages, they were able to recall more color photographs than black-and-white ones. Out of the four color photographs and four black-and-white photographs each subject was exposed to during the test, each subject was able to recall an average of 1.75 of those in color and 1.38 of those in black and white. The difference was not statistically significant, $t(31) = -1.68$, $p>.05$.

Subjects were also asked whether they recognized the photographs -- displayed in both color and black and white -- that they had seen on the newspaper pages mixed amongst a group of photographs they had not seen. Subjects recognized a significantly larger number of photographs when they had been exposed to the original in color than if they had been exposed to the original in black and white, $t(31) = 2.77$, $p<.05$. Subjects recognized an average of 5.84 of the eight photographs shown during the test when they had seen the photographs in color in the experimental newspaper, compared to 4.90 when they had seen the photographs originally in black and white.

Finally, *t* tests were computed to determine whether the number of fixations on a photograph and the total fixation duration on a photograph was related to the recall or recognition of that photograph. The first test found that the average number of fixations on a photograph that was later recalled by subjects was 3.19, while the average number of fixations on a photograph that could not be recalled by subjects was 2.21. The difference of 0.98 fixations is statistically significant, $t(246) = -2.90$, $p<.01$.

The second test found that the average total duration of fixation on a photograph that was recalled by subjects was also significantly different from the average total duration of fixation on a photograph that was not recalled. Subjects fixated for an average of 0.82 seconds on a photograph they recalled, and only 0.57 seconds on one they did not recall. The difference of 0.25 seconds was statistically significant, $t(246) = -2.55$, $p<.05$.

Finally, *t* tests showed the average number of fixations on photographs that were recognized was significantly greater than the average number of fixations on photographs that were not recognized. Additionally, *t* tests showed the average length of fixation duration on photographs that were recognized was significantly greater than the average length of fixation duration on photographs that were not recognized.

Specifically, the average number of times subjects fixated on a photograph they later recognized was 3.15, compared to 1.51 times on a photograph they did not recognized, $t(246) = -5.24$, $p<.01$. The average length of time subjects fixated on photographs they recognized was 0.82 seconds and 0.37 for those they did not recognized. This difference of 0.45 seconds was also statistically significant, $t(246) = -5.24$, $p<.01$.

Discussion

Results from this study suggest that color photographs can be an important tool for the transmission of information in newspapers. Color photographs significantly affect, even change, the overall scan path of the page in some instances. In addition, the use of color significantly aids recognition of photographs printed on the newspaper page.

However, the results also show that color photographs are not always preferable to black-and-white photographs. Factors such as content, position and size may be more important than the use of color or black and white in determining whether people will look at newspaper photographs and how much time they will spend fixating on them.

While this study did not deal with the effects of photographic content, it seems logical that content is the major reason why people look at some photographs and do not look at others. The use of color certainly does not guarantee that people will look at a particular photograph. In this study, only 78% of all color photographs were fixated on. Obviously other factors, such as content, influence the choices people make about what to look at.

This study confirms the importance of a photograph's position in influencing whether or not readers fixate. Subjects in this study were more likely to look at the photograph on the top of the page than the photograph on the bottom of the page. Specifically, 96 of the 124 photographs on the top of the page were fixated on at least once, compared to 82 of the photographs on the bottom of the page.

Furthermore, subjects fixated significantly more times and fixated significantly longer on those photographs displayed on the top of the page, as compared to those on the bottom of the page. The statistics show that color does not appear to be a significant factor in either comparison. Subjects directed an average of 3.30 fixations to the top photograph compared to 1.97 fixations to the bottom photograph. They spend about 0.83 seconds looking at the top photograph and 0.50 seconds looking at the bottom photograph.

The argument for the importance of a photograph's position is further strengthened by looking at the scan path data. In most cases, the eyes begin scanning near the top of the page and move along a fairly uninterrupted path through the content of the entire page. However, when a color photograph is displayed at the bottom of the page and a black-and-white photograph is displayed on the top, the scan path is often significantly impacted or changed. This is not the case when two color or two black-and-white photographs are used on the same page, or even when a color photograph is placed on the top of the page with a black-and-white photograph on the bottom.

Specifically, in the CT/CB treatment, the average order of occurrence of the first fixation on the top photograph was at 6.44, whereas the first fixation on the bottom photograph occurred at 21.11, with 14.67 fixations separating the first fixation on the top photograph and the first fixation on the bottom photograph. In the BT/BB treatment, the first fixation on the top photograph was at the 5.73 order of occurrence, whereas the first fixation on the bottom photograph was at 21.80, a difference of 16.07 fixations. In the BT/CB treatment, the first fixation on the top photograph occurred at 8.71, whereas the first fixation on the bottom photograph occurred at 15.41, a difference of only 6.71 fixations. Finally, in the CT/BB treatment, the first fixation on the top photograph was at the 4.93 order of occurrence, whereas the first fixation on the bottom photograph occurred at 24.71, a difference of 19.79 fixations.

These results indicate that a color photograph on the bottom of the page attracts the reader's attention sooner than a similarly placed black-and-white photograph. Therefore, a color photograph displayed on the bottom of the page disrupts the scan path when used in conjunction with a black-and-white photograph on the top of the page.

Perhaps this phenomenon can be explained by the argument that color photographs possess more visual weight than black-and-white photographs. In other words, they have greater attention value (Brandt, 1943; Dooley & Harkins, 1970; Warner, 1947). This additional visual weight attributed to color may be due to either the functional or decorative qualities of color. Dooley and Harkins (1970) explain that:

> Functional color is color used as an information code, while decorative color is meant simply to attract attention, and the information it carries is redundant and can be removed without degrading the basic information content of the visual. (p. 851)

This property of visual weight may also help explain why the scan path is uninterrupted when both photographs are in color or both are in black and white. In these cases, both photographs have an equivalent visual weight, thereby allowing the eye to flow naturally from the top of the page to the bottom. By the same token, when a color photograph appears on the top of the page and a black-and-white photograph appears on the bottom, once again an uninterrupted scan path is manifest because the visually stronger photograph is on the top of the page where the scan path naturally begins in most cases anyway.

The size of the photograph may be another factor that affects fixation. Because size was controlled in this study by making both photographs occupy an equal amount of space, there are not data to test the effect of a photograph's size on eye movement.

The recall and recognition data collected in this study indicate that color may help to increase recall and recognition, but provide no definitive answer. Subjects recalled more color photographs than black-and-white ones, but the difference is not statistically significant. On the other hand, color significantly facilitated the recognition of photographs. Subjects recognized significantly more photographs when they had been exposed to the original in color.

Perhaps the effects of color on recall and recognition did not fully emerge in this study because of the short exposure time (10 seconds) to each of the experimental pages. In addition, readers who are accustomed to seeing newspaper photographs in both color and black and white, may have learned during their experience in reading newspapers to process the information in a similar fashion. Furthermore, a subject's interest in the content of the newspaper photograph probably is the foremost determinant of whether a particular piece of information is recalled or recognized.

The short exposure time highlights another interesting point. Subjects recalled about 40% of all the pictures they saw on the experimental newspaper pages and successfully recognized about 90% of them. The recall and recognition of photographs seems surprisingly high considering the 10-second exposure time. However, it is consistent with studies (Haber & Standing, 1969; Shephard, 1967) indicated the enormous capacity and durability of pictorial memory.

Finally, the data show that subjects make more fixations and fixate longer on the photographs they can recall and recognize as compared to the photographs they cannot recall or recognize.

These findings add valuable data to the relatively scarce literature on the relationship between eye movements and memory. They support earlier studies showing that recognition memory for pictures increases with the number of fixations or exposure time (Intraub, 1980, 1981; Loftus, 1972; Potter, 1976). Researchers explain that additional fixations are needed to enhance memory because the memory processes of visual images are very volatile. In other words, multiple fixations are needed to make sure that a photograph or a detail from a photograph is remembered.

Finally, and perhaps most importantly, the recall and recognition data are important because they lend additional support to the basic premise of eye-movement research that fixations provide a way to record and measure how people process and perceive visual information.

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